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ABSTRACT

This nine-point plan for reducing the engineer shortage includes a paper outlining the significance of the problem and points toward major causes. Section 1 discusses the American Electronics Association's (AEA) education program. It overviews cause of the problem at the undergraduate and graduate levels and outlines these nine mechanisms: (1) industry-wide standard for giving resources to education, (2) spotlighting of model industry-university programs, (3) formation of regional task forces to work with companies and colleges, (4) assistance to task forces, (5) an AEA Electronics Education Foundation, (6) continuation of the Blue Ribbon Committee on Engineering Education, (7) AEA Standing Committee to provide assistance, (8) industry lobby-networks in major electronics states, and (9) increase in Engineering Education Department staff. Section 2 reviews extent of the engineering shortage. Causes discussed in section 3 include attitudes, undergraduate supply, foreign students, limitations of education's capacity, outdated equipment and facilities, and faculty shortages. Section 4 summarizes the impact of continued shortages; section 5 offers a consensus view on the shortage. Addenda include figures and lists referred to in the body of the report. (YLB)

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Plan For Action To Reduce Engineering Shortage... With Supporting Data

By Pat Hill Hubbard
Manager, Engineering Education
October, 1981

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American Electronics Association

Planting The Engineering Seed Corn

"Academicians compare industry's appetite for BSE graduates to that of starving American Indians of long ago who, to survive the winter, ate the seed corn needed to plant next year's crop."

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INTRODUCTION

The American Electronics Association's 1981 Board of Directors appointed a select group of industry executives and educational leaders to a Blue Ribbon Committee on Engineering Education. The committee's charge has been to study the problem of engineer shortages, certify its existence and degree, identify the major barriers, and recommend a plan for Association action.

On September 15, 1981, AEA's Board approved the following nine-point plan for both short- and long-term redress. A white paper, which outlines the significance of the problem and points toward major causes, is included to provide a philosophical framework to view the direction of remedy the Association will take.

Because of the changing nature of the problem, industry will need to work to solve it for the "long haul." Other areas will clearly need attention down the way. For example, although an adequate supply of qualified engineering students now exists, changing demographics will cause a reduction in the applicant pool and a change in its composition to include more females and minorities and fewer white males. Increased career counseling and math and science "outreach" programs, therefore, will need to be aimed at females and minority high school students. Moreover, the increasing shortage of math and science teachers at the secondary school level, already at a danger point, will predictably reach crisis stage if something does not turn it around soon.

There is engineering seed corn still in the U.S. silos. The electronics industries just need to make a decision to pay the high cost to buy and plant it.

Pat Hill Hubbard, Manager
Engineering Education

One of America's fastest-growing and most economically-prized high technology industries is electronics. Young and dynamic, electronics has had a phenomenal annual growth rate of 17 percent during the past decade.[1] Sales of electronic products by 100 of the major companies reached $152 billion in 1980,[2] bringing the total sales for the larger industry close to $200 billion. A 1981 Panel on Computing and Higher Education quotes a Commerce Department report that says information technology accounts for 46% of the GNP, and computer sales alone bring a $6 billion balance of trade surplus.[3]

The promise of electronics to continue improving the quality of life is threatened by the growing shortage of computer software (CS) and electrical/electronic (EE) engineers. Like critical pieces of technological DNA, engineers are the building blocks of electronics.

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I

AEA ENGINEERING EDUCATION PROGRAM

PROGRAM GOAL: To significantly increase the quantity of engineers while maintaining educational quality.

Problem Statement: An increasing national shortage of engineers threatens to limit the growth of high technology and negatively impact the economic and political leadership of the United States, as well as the continued health and expansion of the electronics industries.

Extent of the Problem: A shortfall exists between supply of engineering graduates and projected industry demands for engineers. The shortfall for the electronics industries alone projects to 25,000 EE/CS baccalaureate engineers annually through 1985. Engineering colleges will need to step up output immediately to meet the needs.

Causes of the Problem at the Undergraduate Level: The shortage of BS degrees is primarily due to a lack of resources, especially faculty, of engineering colleges to handle the oversupply of qualified students.

Degree of Undergraduate Problem: Roughly, only 1 of every 3 qualified applicants is admitted to undergraduate engineering programs because of limited resources. Enrollments, while up 7.2% from a year ago, are straining educational capacity, threatening the quality of education, and lessening the attractiveness of teaching as a career. In response, many colleges are limiting or contracting enrollments, raising admissions requirements, increasing class sizes, etc.

- Laboratory equipment, now 20 to 30 years old, is outdated and in short supply; little is available to teach "new technologies."
- Lab and classroom facilities need upgrading and are in short supply; increased numbers of students will create extra "wear and tear."

- o 10%-to-15% or 2,000 to 2,500 engineering faculty positions are unfilled. Faculty vacancies are nearly 50% in solid-state electronics, computer engineering, and digital systems. Faculty shortages make teaching unattractive (larger classes, longer hours) and affect educational quality.

Causes of the Problem at the Graduate Level: The shortage of MS and Ph.D degrees awarded to U.S. citizens is due to an undersupply of graduate students. After the BS degree students are attracted to jobs with high starting salaries in industry. Incentives to become faculty members (requiring Ph.D) are poor.

Degree of Graduate Problem: 400 fewer MS/EE degrees were granted in 1980 (total of 3,740) than in 1970 (total of 4,150). 350 fewer Ph.D/EE degrees were granted in 1980 (total of 532) than in 1970 (total of 873).

U.S. citizens received 76.5% or 2,859 MS/EEs awarded in 1980.
U.S. citizens received 67.4% or 352 Ph.D/EEs awarded in 1980.

- o Rising tuition costs, low graduate assistance salaries, fewer graduate fellowships, and inadequate facilities make BS-level industry salaries much more attractive than graduate study.
- o There are actual disincentives to pursuing the education required for a faculty career: low academia salaries compared to industry's, high student-to-faculty ratios, poor quality research and teaching equipment, difficulty in gaining external research funding, etc.

What Needs To Be Done:

Short-term: Add resources to immediately expand educational capacity.

Long-term: Add resources to increase the number of Ph.Ds (to do advanced industry research and to become faculty for tomorrow's students) and enhance the quality of engineering education.

What AEA Can Do

1. Expanded educational resources

   A. Increase faculty
      - o AEA adjunct and visiting professors
      - o AEA teaching "chairs"
      - o AEA industry consultancies (salary supplements for new faculty)
      - o Legislative action to increase engineering and computer science faculty salaries (public universities)

   B. Increase and upgrade equipment and facilities
      - o AEA grants
      - o AEA equipment transfers
      - o Legislative action to increase equipment/facilities budgets (public universities)

II. Increase graduate student supply (more Ph.Ds)

   A. AEA graduate student fellowships

   B. AEA co-op programs

How AEA Can Do It (Mechanisms):

1. Set an industry-wide standard for giving resources to education: 2% of a company's R&D expenditures.

   Such resources can be given directly by the company to the college or through an AEA foundation. They can be given in a variety of ways: equipment, industry facilities, adjunct/visiting professors, teaching "chairs," graduate fellowships, general grants of money, etc.

2. "Spotlight" model industry-university programs to encourage companies to duplicate them.

3. Form regional task forces composed of AEA Council Engineering Education (EE) Committees to work with companies and area colleges.

The engineering shortage is a national problem. Engineering colleges produce graduates who are employed all over the United States. The mobility question, however, is also focusing increased interest on area or regionally-located engineering institutions.

AEA's 13 Councils provide a unique organizational structure for addressing the problem from both a local and a national standpoint. Ten states produce 58% of the BSEs (all categories). Four of these "top 10" have AEA Councils.

Council EE Committees can work with local companies to provide industry personnel as part-time and/or full-time faculty for area universities and encourage them to provide additional resources to universities (money to fund teaching "chairs," graduate fellowships, etc.).

4. Provide assistance to the regional task forces with loaned industry executives as "facilitators."

With assistance from AEA Engineering Education staff, loaned industry executive facilitators can assist AEA Council EE Committees in various ways, such as: (1) identify the specific needs of the universities for faculty (background, experience, specialty teaching areas, etc.); (2) help AEA member companies identify and release qualified persons to teach part-time or full-time as the need may be; (3) set up interviews for selection by the schools; (4) assist fund-raising efforts to provide salary supplements/"chairs," graduate fellowships, etc. In states targeted by AEA for legislative activity during 1982, loaned executives can assist AEA's Engineering Education and Government Affairs staffs to identify issues and generate grass-roots support as well as industry input to state governments.

5. Set up an AEA Electronics Education Foundation (EEF) to publicize and promote the Engineering Education Program (records of resources given to education, etc.); to advise and assist companies opting to directly provide resources and undertake programs (promote 1-to-1, company-to-school relationships); and to accept and disburse resources as requested.

6. Continue the Blue Ribbon Committee on Engineering Education into 1982 to complete present planning, make the federal government and the Office of the President aware of the problem and the need for supportive fiscal and tax policies to solve it, and to provide "transition" of program guidance to a Standing Committee.

7. Establish an AEA Standing Committee to provide assistance to Engineering Education staff and general guidance in achieving program goals. It will report periodically to the Board to make recommendations as appropriate.

8. Establish industry lobby-networks in major electronics states to identify and support issues which will help meet program goals (increase state budgets for equipment, etc.).

9. Increase Engineering Education Department staff with 1 full-time position to assist in program management. Staffing and additional travel to facilitate regional task force directions require an addition to current budget.

II

EXTENT OF THE ENGINEERING SHORTAGE

STATEMENT OF THE PROBLEM

The growing shortage of engineers on a national scale threatens to limit the growth of high technology and negatively impact the continued health and vitality of the United States on economical, political, and social levels.

SUPPLY AND DEMAND

The American Electronics Association's recent nation-wide survey, "Technical Employment Projections: 1981-83-85," brings hard data to certify the existence of an engineer shortage (Figure 1 is based on the survey results and indicates the severity of the problem). Note that while the SUPPLY figures are from all U.S. colleges, the DEMAND data is only from the electronics industries.

The DEMAND figures were calculated by using the survey projections as a baseline. The 671 respondents represent $77.7 billion annual sales and 500,000 employees. As this baseline represents approximately one-third of the U.S. total, the figures were multiplied by 3 and compounded annually by 4.98% to account for losses due to promotion into management.[4] The DEMAND reflects new growth only and does not include replacements due to retirement, turnover, or death.

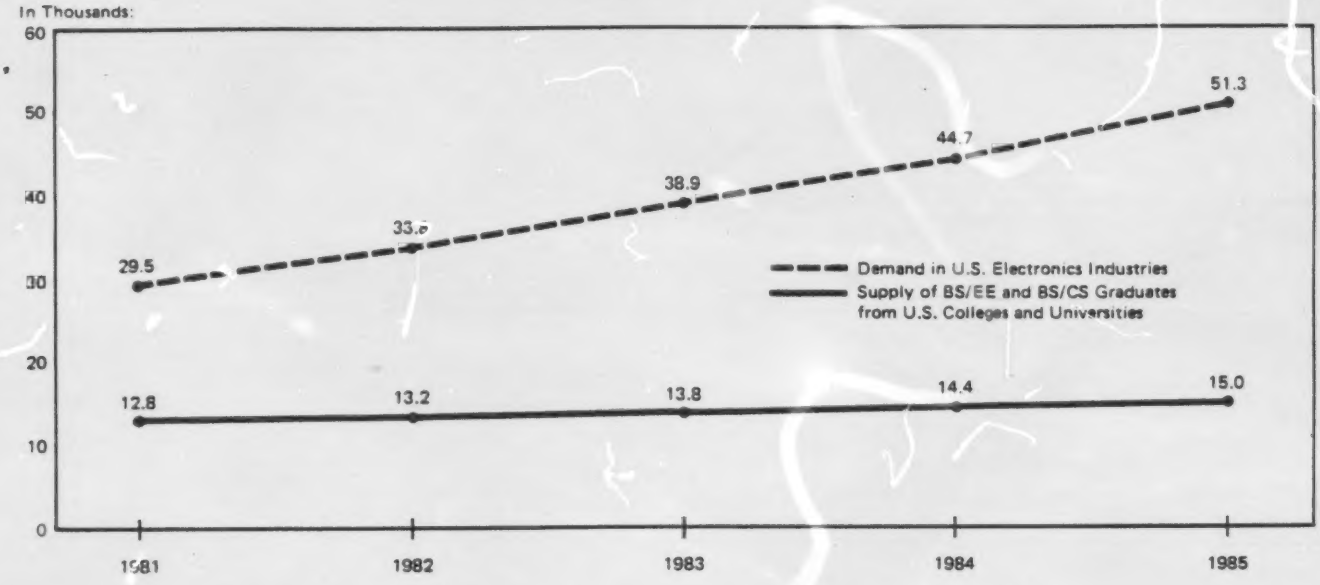
The SUPPLY figures were made by using the number of BS degrees awarded in 1980 as baseline.

The BS/EE projections were made using a 2.6% annual compounded growth rate (ACGR) projected by the U.S. Bureau of Labor.

The BS/CS degree figures were reached using a 12.4% ACGR, duplicating a pattern of 1977-to-1980 degree increases. All degree projections were reduced by 20% to account for graduates who do not take jobs in engineering.[5]

U.S. ELECTRONICS INDUSTRIES

COMPARISON OF PROJECTED SUPPLY AND DEMAND
ELECTRICAL AND COMPUTER ENGINEERS



DATA: AMERICAN ELECTRONICS ASSOCIATION ©

Figure 1

By 1985 the electronic industries' total DEMAND for new BS/EE and CS people projects to be approximately 199,000.

By 1985, total SUPPLY of BS/EE and CS graduates projects to be around 70,000. Assuming electronics industries--to the exclusion of all other engineering-intense industries--can aggressively capture all the graduates, the SUPPLY shortfall by 1985 projects to be around 129,000 or 25,000 annually.

Just to meet the needs of electronics, education must triple its output of EE and CS engineers each year for the next five years.

Strong demands are validated by other measures as well. Deutsch, Shea, and Evans show no let-down in demand for more than three years:

YEAR	ENGINEERING RECRUITMENT INDEX
1978	139
1979	144
1980	138
1981	140 (Average of Jan. & Feb.)

One Fox-Morris survey showed demand for EEs leaped 18.5% during 1980.[6] Another survey by the same group indicated the need for experienced programmers capable of writing applications software jumped 27.3% since mid-1980.[7] The American Society for Engineering Education (ASEE) estimates employers will compete heavily for 1981 engineering graduates; by diploma time, 75% with BS degrees, 73% with MS, and 92% with Ph.Ds will already have jobs.[8]

COSTS TO INDUSTRY

In the wake of the shortage there is a scramble for technical talent which escalates the cost-of-doing-business. The price for search firm location of a $30,000 engineer can be as high as $10,000. And the practice of offering finder's fees has increased. Loral Electronics, for instance, pays $5,000 for referral of an engineer with four years experience. Three Lockheed divisions pay employees $1,000 for each engineer they refer.[9]

Small companies, unable to offer perquisites such as tennis courts and jogging tracks, and who cannot spend huge sums on media-splash advertising and recruitment campaigns are severely disadvantaged. Since innovation and accelerated job growth historically come from small companies, the effect of long-term shortages on them is of special concern.

DEFENSE DOLLARS

Engineering shortages pose a dilemma for defense contractors. President Reagan was recently asked by the press where he thought companies would find technical workers if his defense budget passed. His optimistic reply was to "give industry the money, and it will find the people."

Yet to win defense dollars, company proposals must demonstrate that competent technical talent is already on board or "at hand." A lack of engineers

prevents companies from bidding altogether Some companies "bet-on-the-come" of a defense contract and unnecessarily stockpile people. This practice compounds the shortage problem.

Companies which now have defense contracts are experiencing difficulty in staffing existing vacancies. Rockwell, with 17,000 engineers on the payroll, is looking to hire 900 more for 1981. A company representative expressed concerns about "losing....advanced men to retirement," noting that "quality field replacements are just about impossible to come by."[10] The Pentagon just announced that "because of a shortage of engineers at Vandenberg Air Force Base in California, there will be a 14-month delay in launching the first military payloads aboard the space shuttle."[11]

With high interest rates compounding some sky-priced rental and housing markets, the old formula of moving in large numbers of people to fulfill defense contracts is no longer a given. States like California find the mobility question quite serious. AEA survey data from 313 of the state's 3,500 electronics facilities shows a need through 1985 for new EE/CS level people of 20,557 or 4,111 per year.[12] A state agency's in-house analysis of the new national defense budget's effect determined that 700,000 new jobs---half in manufacturing--are likely to be created in California by 1986 (140,000 per year). Juxtapose these DEMAND figures against the 2,909 EE/CS graduate degrees (all levels) awarded by all public and private colleges in the state in 1980, add the mobility issue, and the problem's magnitude grows.

SOLUTION DOLLARS

Data analysis emphasizes the present shortage of engineers is likely to be exacerbated in the next few years unless industry intervenes. A study of the causes points strongly toward a money-solution.

Simply throwing a "few bucks" towards education in scattered directions brings short-term returns but may have negligible effects on the larger problem. Dollars given to colleges which lack understanding of the expanding need for engineers, whose presidents may reduce the engineering departments' budgets equal to the amount of industries' gifts, help shore up the educational system, but do not affect the problem at hand.

III

CAUSES OF THE ENGINEERING SHORTAGE

STATEMENT OF THE CAUSES

Currently, the shortage in BS graduates is caused by a lack of resources--most seriously in faculty--of universities to educate the oversupply of qualified engineering graduates.

The shortage in MS and Ph.Ds is caused by an undersupply of graduate students resulting primarily from high BS-level industry salaries and disincentives to enter teaching careers, not only limiting industry's progress in advanced research, but clearly reducing the pool from which future faculty come.

ATTITUDES

Some industry people view the cause of undergraduate engineering shortages as a misallocation of resources by university presidents. Why, they ask, don't presidents shift money from declining disciplines like English and move it to expanding ones like engineering?

Education responds to the query in several ways. Some oppose resource shifts because they consider the shortages temporary. Some are unwilling to increase engineering education budgets because of the industry's "fair-weather-friend" behavior. Some are unwilling to fight the institutional pressures involved in terminating tenured professors. And some fear increased engineering budgets will unbalance curricula and jeopardize their status as "comprehensive" universities, even when industry provides the additional monies.

Some educators look at the cause of the graduate student shortages--the pool from which future faculty come--as a result of myopic behavior by industry. Academicians compare industry's appetite for BSE graduates to that of starving American Indians of long ago who, to survive the winter, ate the seed corn needed to plant the next year's crops.

DECLINING BIRTHRATES

If all these philosophical resistances reverse, one economic constraint remains. Declining birthrates predict a substantial decrease in post-secondary enrollments by 1990 (See Addendum A). In 1988 there will be 2,130,000 (14.3%) fewer high school students than in 1980. A decrease in college enrollments means no tuition revenue increase to pay for great shifts of student career interests.

THE UNDERGRADUATE SUPPLY

A decade ago, engineers laid off due to space and defense program cut-backs became a media cause-célèbre. Year-long reports emphasized job losses. Rarely was the public's perspective balanced with information that the unemployment rate for engineers reached only 3.2%, staying but "a brief time before returning to its normal level of about 1%."[13] The public's long memory of the engineering "bust" coupled with Vietnam's anti-technology legacy, therefore, caused young people to avoid engineering careers for several years. This is no longer true. Engineering is the second most favored career choice of today's high school seniors (see Addendum B, Figure 1).

Estimates of the applicant-to-admission rate is placed at about 3-to-1. Dr. Joseph Pettit, President of Georgia Institute of Technology and a member of AEA's Blue Ribbon Committee on Engineering Education, states that his college approves admission for about 1,700 of the approximately 7,000 applicants. Dr. Richard Atkinson, Chancellor of UC San Diego and also a member of the AEA Blue Ribbon group, notes the high quality of today's engineering applicants and says his university, like most others, closes admissions doors the day they open. Dr. Jay Pinson, Dean of Engineering at San Jose State University, states he has "a thousand students 'holding' in other departments, waiting for engineering slots to open."

The schools have accommodated increased numbers of students. Full-time engineering undergraduate enrollments in the nation's 287 engineering colleges and universities are up 7.2% in undergraduate and 7.1% in graduate classes in fall of 1980 from a year ago. Freshmen undergraduate engineering enrollments

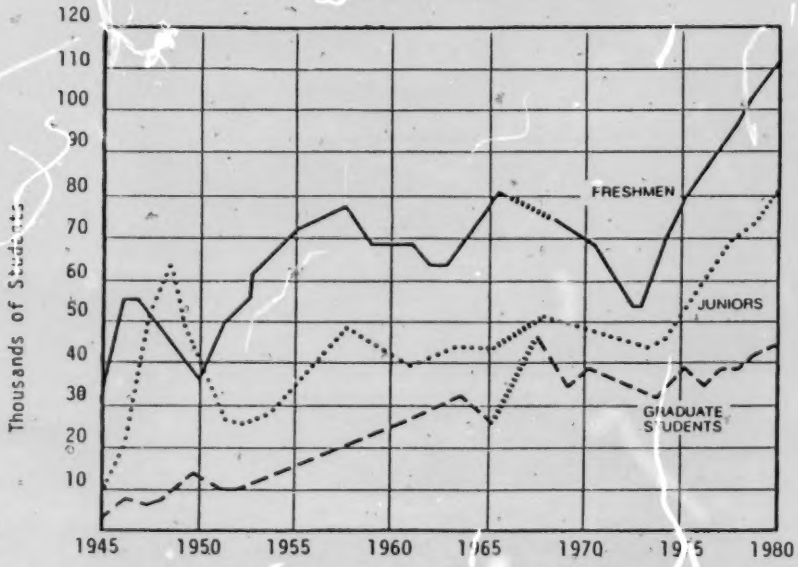
increased 6.2% from the previous year. Females and blacks accounted for 14.1% and 5.1% respectively of the freshman class increase.

FOREIGN STUDENTS

Some concern over increased numbers of foreign students in U.S. schools may be warranted in light of the numbers who return home after graduation and the pressure their added numbers place on already strained educational resources. In 1979, 260,000 foreign students were enrolled in postsecondary educaton (64% in public institutions). That number represents a 300% increase since 1964[14]. In 1980, 6.8% of the engineering undergraduates were foreign students, while 46.3% of the engineering graduate students were foreign students. The increase of foreign students at the graduate level--from 38.7% in 1974 to the present 46.3%--does signal a need to do two things: increase the number of U.S. citizens who pursue graduate study and/or initiate federal policies which allow foreign graduates to remain in the U.S.

The recent jump in engineering enrollments at all levels, however, comes primarily from U.S. citizens--not foreign students. From 1979 to 1980 foreign student undergraduate numbers increased only 0.3% and graduate enrollments only 2.4%. Foreign students in all engineering education fields in 1980 were 40,774 or 9.4% of the total 433,451.

ENGINEERING FULL-TIME ENROLLMENTS 1945-1980



Source: Engineering Manpower Bulletin 58, May 1981
American Society of Engineering Education

INCREASE IN UNDERGRADUATE EE AND CS DEGREES

Since 1977 when BS/EE degrees dropped to 9,837, the lowest number since 1970, there has been a steady increase in EE and CS degrees. (See Addendum B, Figure 2 for EE and CS degrees awarded 1970-1980/all levels):

Year	BS/EEs Awarded	% of Change	BS/CSs Awarded	% of Change
1970	11,291	4.80%	139	167.31%
1971	12,145	1.88%	174	25.18%
1972	12,430	2.35%	359	106.32%
1973	11,844	-4.71%	568	58.22%
1974	11,347	-4.20%	727	27.99%
1975	10,277	-9.43%	599	-17.61%
1976	9,954	-3.14%	796	32.89%
1977	9,837	-1.18%	1,280	60.80%
1978	10,702	8.79%	1,546	20.78%
1979	12,213	14.12%	1,510	-2.33%
1980	13,594	11.31%	1,816	20.26%

2,303 more BS/EEs were awarded in 1980 than in 1970, an increase of 20.4%

DECREASE IN GRADUATE EE AND CS DEGREES

At the graduate level the data reflects a reverse trend. 490 fewer MS/EEs were awarded in 1980 (3,660), or 11.8% less than the 4,150 in 1970. 350 fewer Ph.D/EEs were awarded in 1980, (523) or 40% less than 873 in 1970.

Comparing EE graduates of all levels in 1977 with those in 1970 on a per capita basis, a decrease is evident.

1970 88 EE graduates per one million U.S. population
1977 66 EE graduates per one million U.S. population.[15]

The sales of electronics products over the last 20 years has increased six times. The number of EE graduates has only doubled. An increase of only 5% more EE degrees at all levels has taken place during the last decade: 16,944 in 1970 versus 17,777 in 1980.

LIMITATIONS OF EDUCATION'S CAPACITY

Some people point to the recent engineering enrollments as a sign the shortage is easing. Indeed the percentage of degreed BS/EEs has been rising for the last three years. In 1980, for example, 13,594 BS/EE degrees were awarded--an 11.3% increase over the previous year.

Assuming the 11.3% degree-growth pattern holds steady for the next five years, 94,793 BS/EE degrees would be awarded between 1981-1985. Since only 80% (75,834) is likely to enter the workforce as engineers, these numbers are still a considerable shortfall to the projected DEMAND for 199,000. (See Figure 3.)

It takes four-to-five years for an engineering student to receive a bachelor's degree. To determine the relationship between total engineering enrollments (all fields) and the number of BS/EE degrees granted requires that current degrees awarded be compared with enrollments at least four years previously. The 13,594 BS/EE degrees awarded in 1980, for example, represents 1 degree recipient to every 25 enrollees or 4.0% of the total 337,801 enrollments four years ago.

BS/EE DEGREES IN RELATION TO ENGINEERING ENROLLMENTS ALL FIELDS

School Year	Engineering Enrollments All Fields	Enrollment Increases Over Previous Year All Fields	BS/EE Degrees Awarded/Year	Engineering Enrollments in All Fields Four Years Previously	% of BS/EE Degrees to Enrollments Four Years Previously
1975/76	309,553	31,566	9,954--1976	270,153	3.7%
1976/77	337,801	28,248	9,837--1977	263,003	3.7%
1977/78	374,182	36,381	10,702--1978	277,987	3.8%
1978/79	396,594	22,412	12,213--1979	309,553	3.9%
1979/80	433,451	36,857	13,594--1980	337,801	4.0%
1980/81	469,929	36,478	[15,130--1981*]	374,182	see note A
1981/82	[580,450**]	[110,521**]	[16,840--1982*]	396,594	see note B
1982/83	[646,050**]	[65,600**]	[18,743--1983*]	433,451	see note C
1983/84	.....	.....	[20,861--1984*]	469,929	see note D
1984/85	.....	.....	[23,218--1985*]	[580,450**]	[4.0%**]

Notes:

Brackets [ ] indicate projections.

*Degree-projections are based on 11.3% annual growth.

**Engineering enrollment projections assume continuation of the 4% relationship of BS/EE degrees to enrollments four years previously.

Note A: 15,130 degrees at 4% relationship of degrees-to-enrollments requires enrollment four years previously to have been 378,250. The actual enrollment of 374,182 leaves a 4,068 student shortfall already.
Note B: 16,840 degrees at 4% requires enrollment of 421,000. 396,594 actual enrollment leaves 24,406 shortfall.
Note C: 18,743 degrees at 4% requires enrollment of 468,575. 433,451 actual enrollment leaves 35,124 shortfall.
Note D: 20,861 degrees at 4% requires enrollment of 521,525. 469,929 actual enrollment leaves 51,596 shortfall.

Assuming that the relationship of BS/EE degrees as a percentage of engineering enrollments in all fields continues as it has in the past few years, and taking the high point as 4.0%, enrollment will need to reach 580,450 in the coming school year in order to award 23,218 BS/EE degrees in 1985 (at 11.3% annual BS/EE growth). This will require an increase of 110,521 students. (See Figure 3.)

Unless substantially more engineering students choose electrical engineering majors or unless more who now major in it get degrees, maintaining an 11.3% annual increase of BS/EE degrees will require annual enrollment increases ranging from 65,000 to 110,000.

These increases are unlikely for two reasons. One is history. The largest enrollment increase in the past five years occurred between school years 1978/79 and 1979/80 -- 36,857. As a recent article in the Wall Street Journal notes, engineering schools are "already at capacity" and "crowded schools can't increase enrollment further....some are even cutting back."[16]

The second is demographics. Declining numbers of high school students over the next decade (see Addendum D) will reduce college enrollments, making even the present 36,000+ increase a challenge to maintain.

The strain placed on educational resources by extra numbers of students sets up a "capacity" factor. This "educational bottom line," combined with a diminishing high school population, makes the Bureau of Labor Statistics' 2.6% projection for EE degree-growth understandable and calls for caution in thinking enrollment increases alone are going to provide an answer.

Increasingly educators voice concern as the extra students push resources beyond capacity. They warn that a decline in quality may result.

A 1980 University of New Orleans (UNO) study of 100 engineering schools provides insight into the enrollment-quality relationship (see Addendum C, Figure 1). 66% of the respondent schools felt enrollment was so high that it posed an immediate problem and handled it in a variety of ways.

* 45% (23 out of 51) increased the GPA requirements for transfer students

* 37% (21 out of 56) increased the GPA required of new students entering engineering
* 13% (6 out of 44) increased the prerequisite classes - upper or lower division
* 71% (28 out of 39) reported taking no steps to limit enrollment.

A Western Interstate Commission for Higher Education (WICHE) survey of 15 western engineering schools recently revealed that "most will have to limit enrollments within the next few years; a few of the larger universities are already operating under legislatively imposed university-wide enrollment ceilings."[17]

The present situation in engineering undergraduate education is characterized by plenty of students, but too few resources to educate them without risking a loss in quality.

OUTDATED EQUIPMENT

John Fluke, President of John Fluke Manufacturing and a member of AEA's Blue Ribbon Committee, recently commented that on a visit to his alma mater he found some of the lab equipment he had trained on fifty years ago still in use.

According to an ASEE assessment, the engineering teaching equipment found in most university labs is 20-30 years old and equipment to teach new "growth technologies" is almost non-existent.[18] New technological processes, demanding sophisticated and costly equipment, have sky-rocketed the cost of teaching laboratories. Ohio State estimates installation of modern design equipment at $3 million plus 15% annual maintenance.

The Association of Independent Colleges estimated in 1978 that calculating 6.5 years as the useful life of instructional equipment, $1,500 per year per engineering baccalaurate degree would be needed to keep equipment up-to-date.[19] Applying this formula to last year's BS/EE graduates brings the annual price tag for electrical engineering teaching equipment alone to $20 million.

A distinction should be noted between research and teaching equipment money sources. Grants and contracts largely pay for research equipment.

Academic budgets and industry gifts are a primary source for instructional equipment. Few colleges can afford expensive CAD/CAM and integrated circuit technology teaching equipment and students will graduate without training in these important areas.

Industry requires modern equipment to compete in the marketplace with state-of-the-art technology. As a result, the "ivory research towers" are on industry land today and attract students who might formerly have chosen graduate study and even teaching careers.

OUTDATED FACILITIES

Like equipment, most engineering labs and classrooms are now 30 years old. Federal money to build facilities has come in pennies over the last 20 years.[20] Inflation, OSHA regulations, and laws requiring building accommodations for the handicapped have compounded universities' inability to provide money for upgrade, repair, or expansion of their teaching plants.

STATE ACTION

A few states are awakening to the resource shortage within their public postsecondary schools. They have begun funneling state funds into engineering education.

* University of Wyoming is spending $18 million on engineering facilities expansion.
* New Mexico recently funded a new engineering building at New Mexico State University and allocated $5 million a year for upgrading science and engineering at all state universities.
* At Arizona State University a five-year $32 million dollar program to establish an electronic and computer "center of excellence" by adding new facilities, equipment and a 63% faculty increase is in process.[21]
* The North Carolina General Assembly just allocated $24.4 million for the construction of a micro-electronics center. The North Carolina center will draw resources from five universities, a community college system, and the Research Triangle's private industries.[22]

* California budgeted $2.6 million to improve UC Berkeley's Cory Hall for micro-electronics instruction.

Nationally, however, much remains to be done. ASEE estimates it will take about $40 million per year to update lab equipment and modernize classrooms.[23]

THE MOST CRITICAL PROBLEM - FACULTY SHORTAGES

Though too-little-too-old equipment and facilities are blocking an "increased throughput" of engineering students, the most serious current bottleneck is the faculty shortage.

Of the nation's some 20,000 engineering faculty jobs, 10% to 15% or 2,000 to 2,500 are presently unfilled. In fields such as solid-state electronics, computer engineering, and digital systems, NSF's Stephen Kahne places the shortage closer to 50%.[24]

Why are people turning away from teaching? Why, for instance, did only 8% (13 out of 160) of the new Stanford Ph.Ds choose teaching last year versus an estimate of 50% ten years ago?[25]

THE DOCTORAL RECRUITMENT POOL

The student doctoral pool from which faculty traditionally comes is shrinking. Only very dedicated U.S. students and foreign students who know "they need higher degrees to compete with citizens for the same jobs"[26] go on to graduate study.

Foreign students are an increasing percentage of the EE doctoral pool. Of the 523 Ph.D/EE degrees awarded in 1980, 171 (33%) went to foreign students. Of these, 66% were on student visas and likely to return home.

ENGINEERING Ph.Ds
PERCENTAGE OF FOREIGN STUDENTS

1964 = 19.8%	1977 = 41.5%
1974 = 38.7%	1978 = 45.0%
1975 = 41.3%	1979 = 45.6%
1976 = 42.3%	1980 = 46.3%

Source: National Science Foundation

The majority of foreign students "are of very high caliber, among the best their country has, and graduate in the top fifth of their class."[27] Yet those who wish to remain in the U.S. face a six month to two year immigration process. Cultural and language differences pose an additional challenge for those who enter teaching.

INDUSTRY-ACADEMIA SALARY INEQUITIES

Economics plays a significant role in faculty shortages.

BS graduates lack incentives to continue their education. Graduate assistant salaries average only $4,500 to $5,000 today. Rising tuition, housing and food costs, and the scarcity of fellowship monies (NSF's 1982 budget all but wipes them out) combine with the knowledge that "a young graduate can start at $5,000 more than his old teachers."[28] Few can resist industry's starting salaries of $20,000 to $24,000.

A 1980-81 ASEE Faculty Salary Survey shows the following average nine month salaries:

Professors	$33,295
Associate Professors	$25,793
Assistant Professors	$21,758
Instructors	$15,903

The UNO study (see Addendum C, Figure 2) reveals essentially the same salary pattern and further shows a relationship between salary and size of school.

Several years of doctoral study and five or more years of teaching must occur before academia's salaries become economically interesting--and then rarely more so than industry's.

NON-FINANCIAL TEACHING INCENTIVES

Money has never been the sole reason people choose to teach. The opportunities to do research and promote growth of knowledge in students in a comparatively relaxed atmosphere have been strong attractions.

Research contracts have always been a prime faculty perquisite. NSF research contracts can provide up to 2/9ths of a salary supplement. For

most other types of research contracts and grants, many universities allow up to one-third of the annual nine-month salary. Grants are becoming increasingly difficult to obtain.

As a percent of GNP, industrial R&D spending decreased from 2.1% in 1964 to 1.6% in 1979.[29] In spite of the investment downtrend, R&D spending at universities and colleges was up 3% in 1972-constant-dollars during 1979. Much of it, however, was not spent in idea generation or product development. It was spent meeting governmental and environmental regulations. Data from the center for the Study of American Business shows that the effect of increased government regulations on the cost-of-doing-business rose from $2,240 million in 1974 to $4,823 million in 1979.[30]

Teaching loads, commonly reduced to permit research, are becoming heavy. The University of New Orleans data (See Addendum C, Figure 2) shows the relationship between research and teaching loads. UNO respondents:

36% teach 9-to-11 hours a week
31% teach 12-to-14 hours a week

77% have reduced teaching loads to do research
- 52% receive 1-to-3 hours reduction
- 46% receive 4-to-6 hours reduction

22% responded that research was not a basis for a reduced load.

Academia's former "more relaxed atmosphere" has also been supercharged by high student-to-faculty ratios. For quality education, a ratio of 1 faculty to 20-25 students is considered ideal.[31] The UNO study show that only a few classes remain within the optimal range. (See Addendum C, Figure 3 In small schools of 500 or less students, the faculty-to-student ratio reaches as high as 1-to-118; 500 to 1,500 student schools as high as 1-to-51; 1,500 to 2,000 student institutions up to 1-to-48; and large schools of 2,000 or more 1-to-39.

Outdated and scarce facilities and equipment, insufficient R&D, increased teaching laods and high student-to-faculty ratios have diminished the non-financial incentives. A climate now exists where pay inequities make the final difference.

SEVERITY OF FACULTY SHORTAGES

Almost 94% or 75 of the UNO respondents (see Addendum C, Figure 1) answered "Yes" to the question: "Are you experiencing difficulties in recruiting new, qualified faculty?" Engineering faculty is clearly a scarce commodity.

In June 1980 Dr. John Kemper, Dean of Engineering at UC Davis, surveyed 241 ABET-accredited engineering schools to quantify present and projected faculty shortages. He found 1,800 current faculty vacancies and 335 new openings due to retirement and 380 new vacancies for projected expansion per year. From 1981 to 1990, therefore, 7,525 new openings--an average of 750 per year--will be needed just for retirement and expansion.

Dr. Kemper adds 180 each year to "work off" current vacancies and finds the annual need for new engineering faculty to b 980 per year.[32]

PROJECTED SHORTFALL OF FACULTY

Based on present trends, what is the projected annual shortfall of the teacher supply?

Approximately 2,700 Ph.Ds in engineering are awarded annually. Generally, 1,300 of these go to foreign students. 33% of these Ph.Ds have temporary resident status[33] and are likely, because of growing sensitivity to the American "brain drain," to return home.

The pool of U.S. students and foreign ones who remain after graduation comes to about 2/3 of the total degree recipients, or 1,800 people. Whereas in the 1960's 1-out-of-3 Ph.Ds went into teaching, today only 1 in 4 does.[34] Applying this 25% formula to the 1,800 suggests a supply of only 450 new faculty each year.

Dr. Daniel Drucker, Dean of College of Engineering at University of Illinois, Urbana-Champaign, says the supply is actually smaller, less than 300, since "quality instruction of undergraduates requires selection from among the upper third (or higher) of all Ph.Ds."[35] Whether 300 or 450 are available, the shortfall to the needed 1,000 is still large.

Assuming that 2/3 of the total Ph.D engineering graduates continue to enter U.S. employment and that they return to the 1-out-of-3-who-choose-to-teach formula, we will need to increase the supply of doctoral-level engineers by 1,300 each year (to a total of 4,000 doctoral graduates) to receive the needed 1,000 faculty.

IV

EFFECT OF CONTINUED SHORTAGES

ECONOMIC, POLITICAL, AND SOCIAL IMPACT

The United States is still the most productive country in the world. Yet while others improve their ratio of output-per-worker, America does not--dropping from a WWII 2.9% increase to a minus 0.9% in 1979.

Japan's productivity makes U.S. industries jog faster to run the economic mile. On a per capita basis, Japan has fewer than 1/20th the lawyers, 1/7th the accountants, but 5 times as many engineers as the United States.[36]

The Soviet Union's double time to reach "scientific and technological supremacy"--graduating 6 times as many undergraduate engineers as the U.S.[37]--causes discomfort in America's national defense arenas.

According to a 1977 NSF study, high technology has twice the productivity, triple the real growth, six times fewer price increases, and nine times more employment when compared to low technology industries.[38] Electronics in particular holds the promise of winning on the economic, political, and social fronts--if the engineer shortages are reversed.

> "The lack of electronic and computer science engineers may be the single most important factor limiting the growth and continued vitality of electronics industries."
>
> Dr. William Perry, Partner, Hambrecht & Quist
> Former U.S. Undersecretary of Defense for
> Research and Engineering

V

VIEWS ON THE SHORTAGE

A variety of views on the shortages of engineers has been expressed in professional associations and trade journals. A consensus is forming. Stephen Kahne, Director of the Division of Electrical, Computer, and Systems Engineering at the National Science Foundation (NSF) puts the matter into perspective:

> It is no longer an open question whether the shortage of electrical engineers in the United States is or is not a crisis. It is. Sooner or later every U.S. industry dependent upon electrical engineering will be affected--and there are more such industries now than ever. Toy and automobile manufacturers, even textile and clothing companies, have discovered the value of electronics and computer-based systems in their products or manufacturing processes. Indeed, these new industries, previously unaffected by electrical engineering in any significant way, are the hidden factor that invalidates traditional market surveys of future needs for EEs. It is hard to predict the growing need for electronics specialists in sectors of the economy that never before employed them.[39]

REFERENCES

[1]Ray Stata, President and Chairman, Analog Devices, Inc., "Needed: A Plan for Educating Engineers." Electronics, April 24, 1980, p. 26.

[2]"The Electronic Business 100." Electronic Business, February 1981, p. 64.

[3]Robert G. Gillespie, Vice Provost for Computing with Deborah A. Dicaro, Research Associate, University of Washington. Computing and Higher Education: an Accidental Revolution, 1981, p. 5.

[4]Electronics industries' annual percentage of promotion of exempt employees into management established by survey of AEA Industrial Relations Committee, 1980.

[5]Estimated by National Science Foundation and American Society for Engineering Education.

[6]Quote by Walter V. Nichols, Vice President of Fox-Morris Personnel Consultants, San Francisco. Electronic Design, September 1980.

[7]"Briefs: Information Processing." Business Week, August 3, 1981, p. 68F.

[8]Scientific, Engineering, and Technical Manpower Comments, Washington, D.C., June 1981, p. 5.

[9] Wall Street Journal, July 14, 1981, p. 1.

[10] John Radick, "Firms Vying for Scarce Engineering Talent," Electronic News, June 15, 1981, p. 40.

[11] Gerald F. Seib and Roy J. Harris, Jr., "Defense Tactics: In Military Buildup, Big Contractors Face Supplier Bottlenecks; Where Are the Engineers?" Wall Street Journal, August 21, 1981, p. 11.

[12] Technical Employment Projections Survey: 1981-83-85. American Electronics Association, Palo Alto, California, June 1981, p. 76.

[13] J. D. Kemper, Dean of Engineering, UC Davis, "Graduate Enrollments in Engineering; Meeting National Needs for Productivity," July 1980, p. 9. Source reference: Quarterly Unemployment Rates for Engineers Released, Engineering Manpower Highlights, Pub.No. 225, Engineers Joint Council, New York, November 1972.

14 Stephen Kahne, NSF Presentation, May 7, 1981. Slide No. ECS 81-1756, 4-1-81.

15 The International Microelectronic Challenge. The Semiconductor Industry Association, Cupertino, California, May 1981, p. 29.

16 Roger Lowenstein, "Two-Edged Sword: Surge in Engineering Enrollment Begins to Ease Industry's Shortages but Stirs Trouble at Colleges." Wall Street Journal, August 26, 1981, p. 48.

17 "Can Higher Education Meet the Need for Technical Manpower?" WICHE Reports. Summer, 1981, p. 11.

18 Ward Worthy, "Chemical Education Falls on Hard Times." C & EN, February 9, 1981, p. 45.

19 Task Force Chaired by Robert H. Page, Texas A&M University, "Data Related to the Crisis in Engineering Education." March 1981, AAES, ASME, ASEE, p. 11.

20 Issues in Engineering Education, a Framework for Analysis, Task Force on Engineering Education of the National Academy of Engineering. Washington, D.C., April 1980, p. 13.

21 WICHE, p. 12.

22 "Micro Center Gets $24.4 Million From Legislature." Future State, Mark Ernsberger, ed., First Union National Bank, Charlotte, North Carolina, August 1981.

23 Worthy. C & EN, p. 45.

24 Stephen Kahne, National Science Foundation, "A Crisis in Electrical Engineering Manpower." IEEE Spectrum, June 1981, p. 50.

25 Summary, Meeting of the Engineering Manpower Task Force, Business-Higher Education Forum, St. Louis, Missouri, April 7, 1981, p. 3. American Council on Education, Washington, D.C.

26 "Wanted: U.S.-born Graduate Students." Chemical Week, June 24, 1981, p. 45.

27 Ibid., p. 46.

[28]Trends: "The Vanishing Professor." Forbes, July 20, 1981, p. 8.

[29]"The Problem: The Decline in U.S. Productivity." Business Week, June 30, 1980, p. 60.

[30]Kahne, Slide Presentation, 4-1-81. ECSE81-1049, 12-18-80.

[31]Wm. S. Janna, University of New Orleans, "The Enrollment Crunch: A National Survey." Engineering Education, April 1981, p. 706.

[32]Kemper, "Graduate Enrollments In Engineering," p. 8.

[33]NSF and NRC, Summary Report, "Doctorate Recipients from U.S. Universities." 1979.

[34]"National Crisis: A Severe Engineering Faculty Shortage," Shakertown Conference, December 3 and 4, 1980, Pleasant Hill, Kentucky. Shakertown at Pleasant Hill, Kentucky, Inc., Harrodsburg, Kentucky, 40330, p. 1.

[35]Daniel C. Drucker, Dean, College of Engineering, University of Illinois at Urbana-Champaign, Statement before Subcommittee on Science Research and Technology of the Committee on Science and Technology, U.S. House of Representatives, March 3, 1981, p. 5.

[36]Claudia Deutsch. Business Week, July 6, 1981, p. 105.

[37]Catherine P. Ailes and Frances W. Rushing, "A Summary Report on the Educational Systems of the U.S. and the Soviet Union: Comparative Analysis." Prepared for NSF, SRI International, Final Report, March 1980, p. iii.

[38]"Revitalizing the U.S. Economy." Business Week, June 30, 1980, p. 103.

[39]Kahne. IEEE, Spectrum, p. 50.

Summary of enrollment in educational institutions[1], with projections, by level of institution: Fall 1970 to fall 1988

Fall of year	Total enrollment	Elementary schools (Grades K–8)	High schools (Grades 9–12)	Institutions of higher education
		(In thousands)		
1970	59,899	36,686	14,632	8,581
1971	60,152	36,088	15,116	8,948
1972	60,000	35,569	15,216	9,215
1973	59,982	34,999	15,380	9,603
1974	60,340	34,584	15,532	10,224
1975	61,063	34,174	15,704	11,185
1976	60,507	33,768	15,727	11,012
1977	59,955	32,951	15,720	11,284
1978	58,948	32,061	15,628	11,259
		Projection		
1979	58,129	31,376	15,245	11,508
1980	57,382	30,974	14,797	11,611
1981	56,602	30,614	14,298	11,690
1982	55,695	30,217	13,808	11,670
1983	55,381	30,273	13,495	11,613
1984	55,122	30,208	13,422	11,492
1985	55,111	30,257	13,496	11,358
1986	55,292	30,675	13,402	11,215
1987	55,576	31,369	13,103	11,104
1988	55,938	32,223	12,667	11,048

[1] Includes public and private institutions.

NOTE: Details may not add to totals because of rounding.

SOURCE: U.S. Department of Health, Education and Welfare, National Center for Education Statistics, *Projections of Education Statistics to 1988–89*, 1980.

ADDENDUM B

Figure 1

Source: National Opinion Research Center

Reported in Manpower Comments, May, 1981, p. 26.

FIELD OF COLLEGE STUDY PLANNED BY HIGH SCHOOL SENIORS

	1980	1972
Business	22%	13%
Engineering	10%	5%
Health services	8%	12%
Preprofessional	8%	—
Education	6%	12%
Computer and information science	5%	2%
Social sciences	5%	17%
Art	4%	3%
Communications	4%	2%
Vocational or technical	3%	3%
Biological sciences	3%	10%
Agriculture	2%	3%
Architecture	2%	2%
English	2%	3%
Home economics	2%	2%
Music	2%	3%
Physical science	2%	3%
Foreign language	1%	1%
Mathematics	1%	2%
Philosophy or religion	1%	1%
Other fields	4%	0.5%

Figure 2 U.S. ENGINEERING GRADUATES

NUMBER OF DEGREES

ELECTRICAL ENGRS

YEAR	B.S.	M.S.	PH.D.	TOTAL
1970	11921	4150	873	16944
1971	12145	4359	899	17403
1972	12430	4352	850	17632
1973	11844	4151	820	16815
1974	11347	3702	700	15749
1975	10277	3587	673	14537
1976	9954	3782	644	14380
1977	9837	3674	574	14085
1978	10702	3475	524	14701
1979	12213	3335	545	16093
1980	13745*	3740*	523	18008*

*Errata sheet from Engineering Manpower Commission corrects 1980 BS/EE degrees to 13,594, MS/EE to 3,660, total all degrees to 17,777.

COMPUTER ENGRS

YEAR	B.S.	M.S.	PH.D.	TOTAL
1970	139	183	34	356
1971	174	250	44	468
1972	359	627	83	1069
1973	568	589	96	1253
1974	727	723	83	1533
1975	592	678	107	1384
1976	796	718	90	1604
1977	1280	802	136	2218
1978	1546	986	123	2655
1979	1510	1074	190	2774
1980	1816	1262	159	3237

ANNUAL % GROWTH

ELECTRICAL ENGRS

B.S.	M.S.	PH.D.	TOTAL
4.80	2.49	1.75	4.07
1.88	5.04	2.98	2.71
2.35	-0.16	-5.45	1.32
-4.71	-4.62	-3.53	-4.63
-4.20	-10.82	-14.63	-6.34
-9.43	-3.11	-3.86	-7.70
-3.14	5.44	-4.31	-1.08
-1.18	-2.86	-10.87	-2.05
8.79	-5.42	-8.71	4.37
14.12	-4.03	4.01	9.47
12.54	12.14	-4.04	11.90

COMPUTER ENGRS

B.S.	M.S.	PH.D.	TOTAL
167.31	54.17	54.55	84.54
25.18	35.14	29.41	30.73
106.32	150.80	88.64	128.42
58.22	-6.06	15.66	17.21
27.99	22.75	-13.54	22.35
-17.61	-6.22	28.92	-9.72
32.89	5.90	-15.89	15.90
60.80	11.70	51.11	38.28
20.78	22.94	-9.56	19.70
-2.33	8.92	54.47	4.48
20.26	17.50	-16.32	16.69

SOURCE: ENGINEERING MANPOWER COMMISSION

The Rosen Electronics Letter, December 31, 1980

Figure 1

Engineering College Limits on Enrollment and Class Size, 1980.

College Enrollment Range	Enrollment increases 0-5%	6-10%	11-15%	16-20%	21-25%	over 25%		A	B	C a	C b	C c	C d	D	E	Type of Course	Average Class Size Limit ≤15	15-20	21-25	26-30	31-35	36-40	41-45	46-50	over 51
< 500	3	9	2	1	2	1	Y	13	12	2	1	1	14	16	18	Service		1	2	8	2	2		3	3
							N	8	7	7	10	8	2	5	3	Non		1	8	2	2	4	1	2	
500-1500	3	9	6		3	3	Y	18	15	8	9	2	8	15	22	Service				8	5	3		3	6
							N	8	11	10	10	14	5	11	1	Non		2	4	5	1	2		2	5
1500-2000	3	6	6	4	1		Y	11	15	7	5	3	4	15	21	Service			1	2	5	1	2	3	6
							N	5	5	7	11	9	4	7	1	Non			3	7	2	2	1	4	3
> 2000	1	7	2	1			Y	7	9	6	6	0	4	3	14	Service				2	2	1	1	2	
							N	6	3	4	4	7	0	7	0	Non			1	1	4	1		2	2

A—Is this (the enrollment increases in the college) unusually high?
B—If appropriate, has the enrollment increase presented a problem which needed immediate attention?
C—Several questions on whether or not steps were taken to limit enrollment:
  a) Increasing the GPA requirement of transfer students.
  b) Increasing the GPA requirement of students entering engineering.
  c) Raising the prerequisites of lower and/or upper level courses.
  d) No steps were taken to limit enrollment.
D—As necessary, have new engineering positions been provided at your institution to maintain a "manageable" student faculty ratio?
E—Are you experiencing difficulties in recruiting new, qualified faculty?

Figure 2

Engineering Faculty Salaries, 1980.

College Enrollment Range	Average Teaching Load 3-5 hrs.	6-8 hrs.	9-11 hrs.	12-14 hrs.	over 15 hrs.		A	B 1-3 hrs.	4-6 hrs.	over 6 hrs.	Salary of Graduate Assistant 9-Month Contract 30-35 K	35-40 K	40-45 K	45-50 K	50-55 K	55-60 K	65-70 K	over $7,000	Salary of Assist. Prof. 9-Month Contract 16-17 K	17-18 K	18-19 K	19-20 K	20-21 K	21-22 K	over 22 K	Salary of Assoc. Prof. 9-Month Contract 22-23 K	23-24 K	24-25 K	25-26 K	26-27 K	over 27 K
< 500	1	2	11	8		Y	9	7	4		2	7	1		1		1	1	1	6	3	6	3	2	3	6	7	2	2	2	1
						N	7																								
500-1500	1	6	9	10		Y	21	12	6		3	7	3	3		2			1	3	7	2	5	6	3	4	9	4	2	2	3
						N	5																								
1500-2000		12	5	5		Y	17	4	9	1	2	4	10	2		1	1	1		3	2	4	4	10	1	3	5	5	3	4	2
						N	2																								
> 2000	1	4	6	3		Y	9	3	4		1	2	1	3	4		1	2	1	1	3	2	2	3	1	3	1	1	5		
						N	2																								

A—Is research a basis for reduction in teaching load?
B—If so, how much of a reduction?
Note: Assistant and associate professor salaries are average starting salaries for an individual starting work in fall 1980.

Figure 3

Departments of Electrical Engineering, 1980.

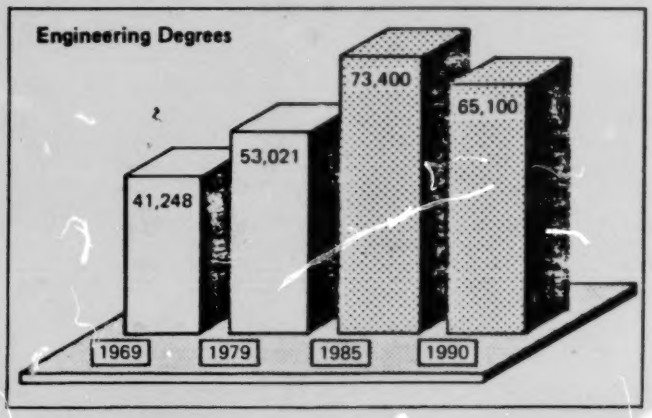
College Enrollment Range		Student/Faculty Ratio	No. of Faculty	Enrollment increases 0-5%	6-10%	11-15%	16-20%	21-25%	over 25%
< 500	Hi	118	30						
	Lo	8	4	2	5	4	2	1	2
	Av	25.2	10.6						
500-1500	Hi	51.5	19						
	Lo	11	4	5	3	5	2	3	
	Av	23.2	10.4						
1500-2000	Hi	48.4	38						
	Lo	5	9	2	8	1	6		4
	Av	20.1	20.7						
> 2000	Hi	39.9	100						
	Lo	13.7	4	1	6	2			2
	Av	24.0	44.5						

SOURCE: William S. Janna, University of New Orleans, "The Enrollment Crunch: A National Survey." Engineering Education, April 1981, pp. 706-707.

ADDENDUM D

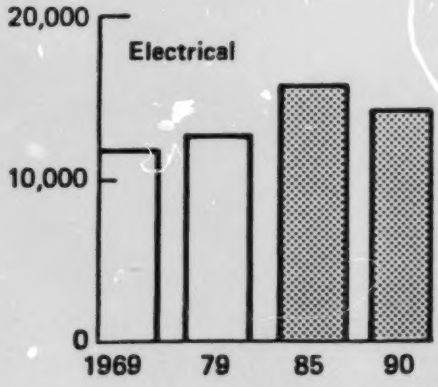
"EFFECTS OF DEMOGRAPHICS ON ENGINEERING ENROLLMENTS"

Chart 1–Total Bachelor's degrees in engineering



The projected increase in engineering degrees to 1985 reflects dramatic increases in engineering enrollments as documented by NCES[2] and the Engineering Manpower Commission.[3] The decline in 1990 reflects demographic changes – decreases in the college-age population – which are expected to impact at that time. The decline should result in degree outcomes that are lower than the 1985 projections for total engineering.

Source: National Center for Education Statistics
February 13, 1981
Bulletin NCES 81-406



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ADDENDUM E

AEA BLUE RIBBON COMMITTEE ON ENGINEERING EDUCATION

Committee Chairman
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John A. Young, President and Chief Executive Officer
Hewlett-Packard Company

ADDENDUM F

TOP 10 STATES AWARDING EE/CS DEGREES
1979 - 1980

State	Bachelor's	Master's	Doctor's	TOTAL
1. California	1,626	1,123	160	2,909
2. New York	1,621	609	73	2,303
3. Massachusetts	881	307	49	1,237
4. Pennsylvania	887	198	34	1,119
5. Illinois	750	289	64	1,103
6. Michigan	843	197	15	1,055
7. Texas	680	274	37	991
8. Ohio	640	279	33	952
9. Indiana	488	101	29	618
10. Missouri	507	82	21	610
Top 10 Total	8,923	3,459	515	12,897
U.S. Total	15,410	4,914	682	21,006
Top 10 Share of Total	58%	70%	76%	61%

SCHOOLS AWARDING THE MOST ENGINEERING DEGREES
1979 - 1980

from Engineering Manpower Commission, 1980

ALL ENGINEERING DEGREES COMBINED

Bachelor's		Master's		Doctor's	
Purdue	1442	Stanford	770	MIT	162
U Illinois (Urbana)	1257	MIT	673	U Illinois (Urbana)	156
Penn State	1136	Cal Berkeley	571	Cal Berkeley	131
Texas A & M	1081	Poly Inst. NY	512	Stanford	110
Georgia Tech	985	U Michigan(Ann Arbor)	415	Purdue	91
U Michigan (Ann Arbor)	917	U Illinois (Urbana)	406	Cornell	82
U Missouri (Columbia)	794	USC	397	Ohio State	63
U Missouri (Rolla)	768	Geo. Washington U	317	USC	62
U Washington	766	Purdue	295	UCLA	58
Virginia Tech	762	Georgia Tech	294	Northwestern	53

EE DEGREES

U Illinois	293	Stanford	216	MIT	48
Purdue	275	USC	158	Stanford	33
MIT	270	MIT	151	USC	32
U Missouri (Col.)	254	Georgia Tech	109	U Illinois	32
Georgia Tech	237	Purdue	96	Purdue	25
U Washington	204	Poly Inst NY	91	UC Santa Barbara	21
Penn State	199	U Illinois	90	Cornell	15
U Minnesota	188	Rensselaer Poly	80	U Texas	11
U Texas	176	Ohio State	71	Ohio State	10
Virginia PI	171	Cornell	68	U Mo. (Columbia)	9
				U Syracuse	9

CS DEGREES

Cal Berkeley	256	Cal Berkeley	147	Cal Berkeley	31
U Illinois	118	Poly Inst NY	94	MIT	17
Oregon State	106	Northwestern	70	U Illinois	15
Texas A & M	87	U Michigan	61	Purdue	12
U Michigan	78	USC	56	Northwestern	12
Michigan State	73	U Pennsylvania	51	UCLA	11
UC San Diego	61	Ohio State	45	Princeton	11
Connecticut U	58	UCLA	44	Ohio State	10
Rensselaer Poly	52	U Illinois	41	U Washington (Mo.)	7
U Illinois	49	S. Clara U	40	Cornell	7
CC New York	49	U Oklahoma	40		